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(54) **WRIST-WORN COMMUNICATION DEVICE**

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(30) **Foreign Application Priority Data**

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H01Q 1/48	(2006.01)
H01Q 5/00	(2015.01)
H01Q 5/314	(2015.01)
H01Q 9/30	(2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 1/273*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 5/314*** (2015.01); *H01Q 9/30* (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/273; H01Q 1/48; H01Q 5/30; H01Q 5/314; H01Q 5/321; H01Q 5/357; H01Q 5/364; H01Q 5/371; H01Q 9/16; H01Q 9/20; H01Q 9/30; H01Q 9/40

See application file for complete search history.

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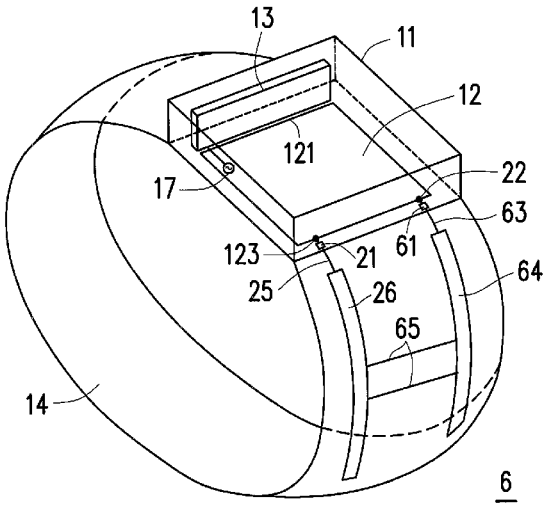
(57) **ABSTRACT**

A communication device, including a device casing, an external connection element, and a first metal element, is provided. A ground element and an antenna element are disposed in the device casing. The ground element has a first edge, a second edge, and a first connection point. The first edge and the second edge are opposite to each other. The first connection point is disposed near or at the second edge. The antenna element is disposed near the first edge. The external connection element is formed by a non-conductive material and is outside the device casing. The external connection element has a belt-like structure and is combined with the device casing to substantially form a loop structure. The first metal element is supported by the external connection element and is coupled to the first connection point of the ground element.

8 Claims, 4 Drawing Sheets



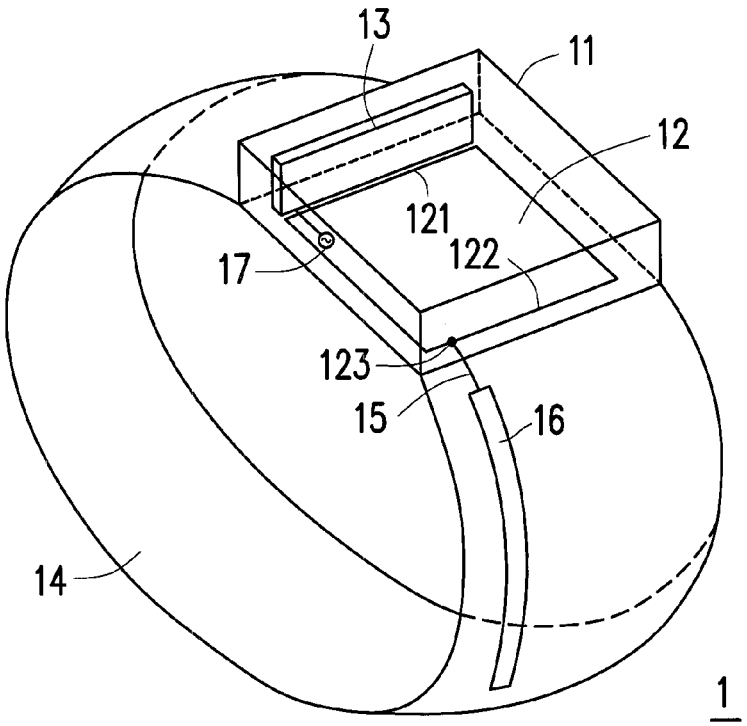

13
11
12
121
122
17
123
15
16
14
1

FIG. 1A

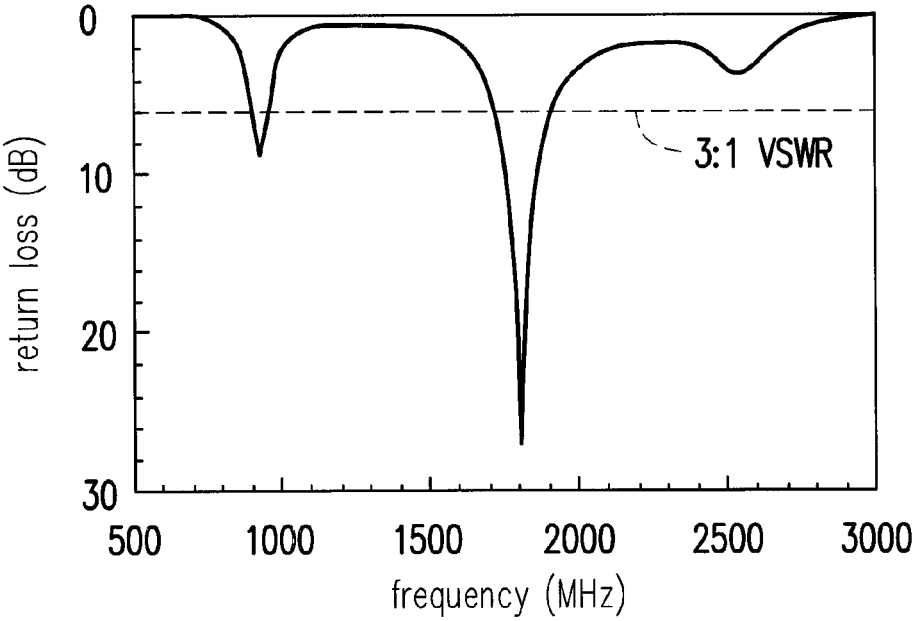

0
10
20
30
return loss (dB)
3:1 VSWR
500
1000
1500
2000
2500
3000
frequency (MHz)

FIG. 1B

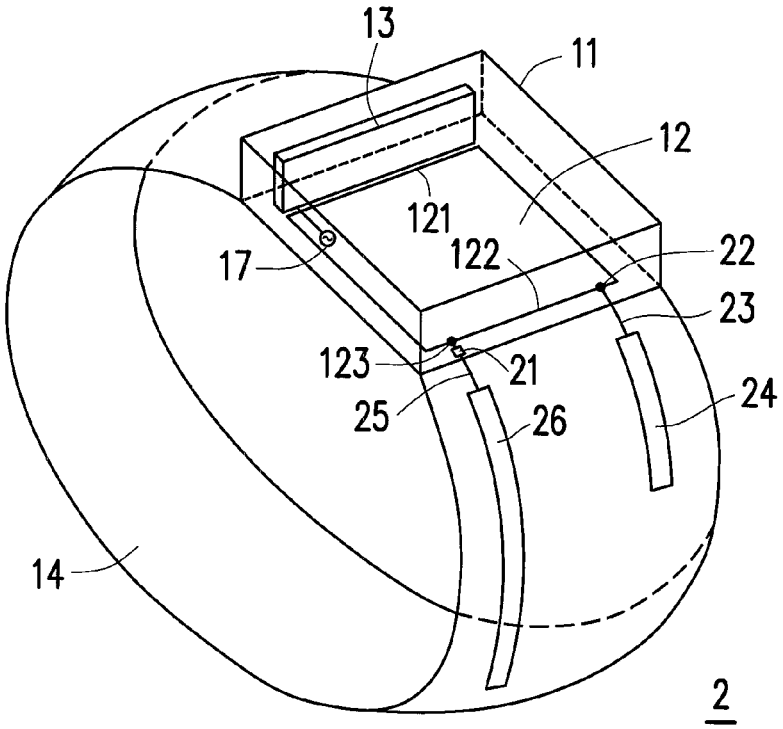

13
11
12
121
122
17
22
23
123
21
24
25
26
14
2

FIG. 2

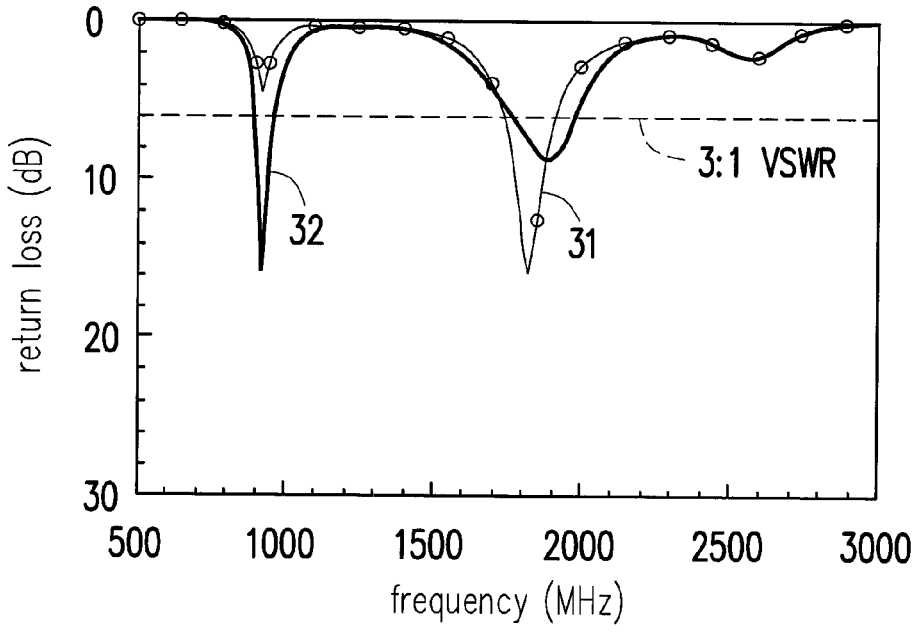

0
10
20
30
return loss (dB)
3:1 VSWR
32
31
500
1000
1500
2000
2500
3000
frequency (MHz)

FIG. 3

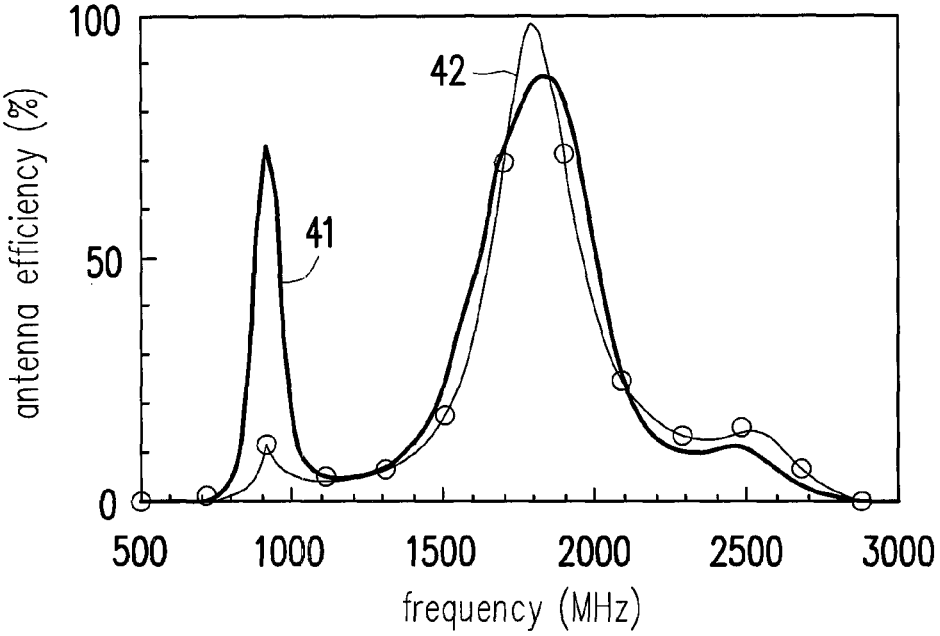

100
50
0
antenna efficiency (%)
42
41
500
1000
1500
2000
2500
3000
frequency (MHz)

FIG. 4

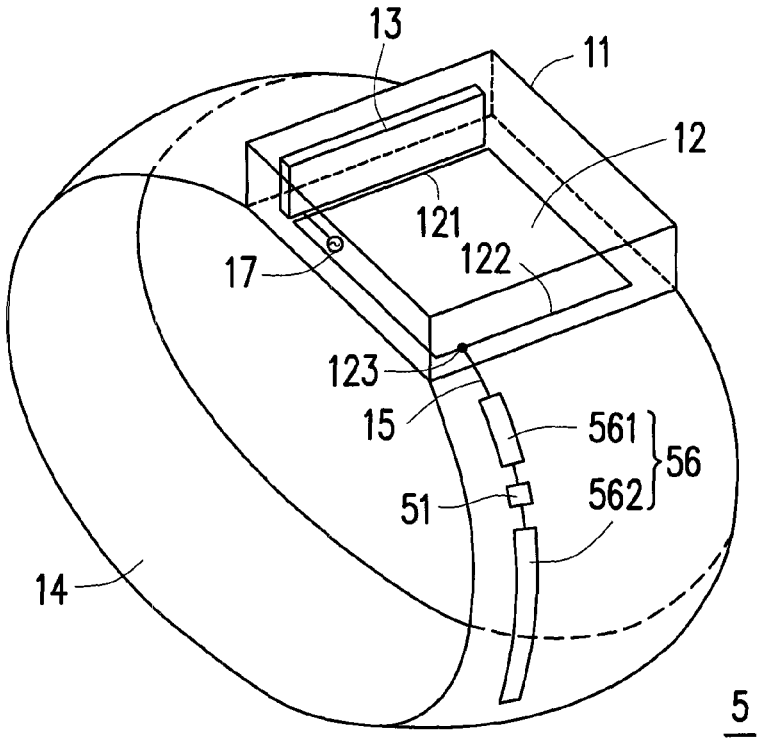

13
11
12
121
122
17
123
15
561
56
562
51
14
5

FIG. 5

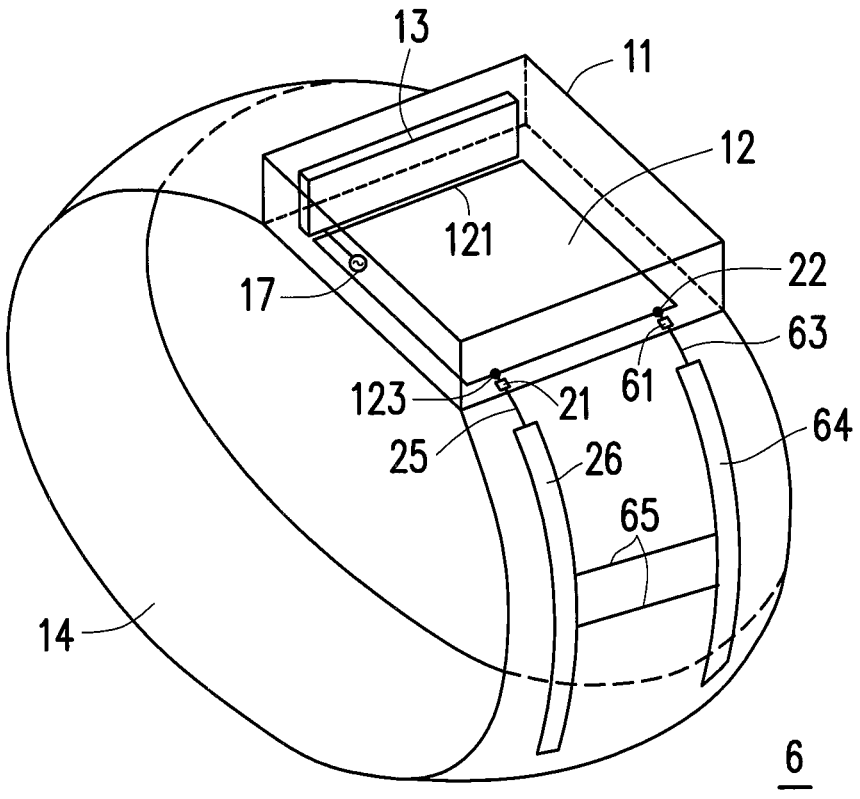


FIG. 6

WRIST-WORN COMMUNICATION DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial no. 102132605, filed on Sep. 10, 2013. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a communication device and particularly relates to a wrist-worn communication device.

2. Description of Related Art

As the technology of mobile communication advances in the recent years, mobile communication devices are being developed to provide more and diverse functions. Because of the trend of the market and expectation of the consumers, wearable communication devices (e.g. smart watch, smart glasses, etc.) are drawing more and more attention. In particular, the design of a communication device for smart watches needs to have the characteristics of being compact in size and easy to wear. However, such a design may result in an excessively small ground plane and cause that the antenna element of the communication device cannot be operated in a low frequency band of mobile communication (e.g. the frequency band of 900 MHz). Therefore, how to enable an antenna element, applicable to a wrist-worn communication device, to perform multi-band operation to cover the low frequency band has become an important issue.

SUMMARY OF THE INVENTION

The invention provides a communication device, in which a device casing and an external connection element form a loop structure, so that the communication device is applicable to a smart watch. In addition, a metal element is provided outside the device casing, and the metal element is supported by the external connection element and coupled to a ground element in the device casing. Thus, the ground element effectively increases an equivalent resonant length thereof, so as to effectively excite a resonant mode of an antenna element in the device casing and cover multi-band operation of mobile communication (e.g. frequency bands of GSM900/1800/1900).

A communication device of the invention includes a device casing, an external connection element, and a first metal element. A ground element and an antenna element are disposed in the device casing. The ground element has a first edge, a second edge, and a first connection point. The first edge and the second edge are opposite to each other. The first connection point is disposed near or at the second edge. The antenna element is disposed near the first edge. The external connection element is formed by a non-conductive material and is outside the device casing. The external connection element has a belt-like structure and is combined with the device casing to substantially form a loop structure. The first metal element is supported by the external connection element and is coupled to the first connection point.

To make the aforementioned and other features and advantages of the invention more comprehensible, several embodiments accompanied with drawings are described in detail as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the invention and, together with the description, serve to explain the principles of the invention.

FIG. **1**A is a schematic view showing the structure of a communication device according to the first embodiment of the invention.

FIG. **1**B is a diagram showing a return loss of an antenna element according to the first embodiment of the invention.

FIG. **2** is a schematic view showing the structure of a communication device according to the second embodiment of the invention.

FIG. **3** is a diagram showing a return loss of an antenna element according to the second embodiment of the invention.

FIG. **4** is a diagram showing an antenna efficiency of the antenna element according to the second embodiment of the invention.

FIG. **5** is a schematic view showing the structure of a communication device according to the third embodiment of the invention.

FIG. **6** is a schematic view showing the structure of a communication device according to the fourth embodiment of the invention.

DESCRIPTION OF THE EMBODIMENTS

FIG. **1**A is a schematic view showing the structure of a communication device according to the first embodiment of the invention. A communication device **1** includes a device casing **11**, an external connection element **14**, and a first metal element **16**. A ground element **12** and an antenna element **13** are disposed in the device casing **11**. The ground element **12** has a first edge **121**, a second edge **122**, and a first connection point **123**. The first edge **121** and the second edge **122** are opposite to each other. The first connection point **123** is disposed near or at the second edge **122**. The antenna element **13** is disposed near the first edge **121**. In addition, a signal source **17** is coupled to the antenna element **13** for exciting the antenna element **13**.

The external connection element **14** is formed using a non-conductive material and is disposed outside the device casing **11**. The external connection element **14** has a substantially belt-like structure, and two ends of the belt-like structure are coupled to two opposite sides of the device casing **11** respectively. Accordingly, the external connection element **14** and the device casing **11** substantially form a loop structure. In actual application, with the loop structure, the user may wear the communication device **1** on his/her wrist to carry around and use the communication device **1** easily. In other words, the communication device **1** is a wrist-worn communication device, for example, which is applicable to a smart watch.

The first metal element **16** is disposed outside the device casing **11** and supported by the external connection element **14**. For example, the first metal element **16** can be embedded in the external connection element **14** and includes at least a metal wire or a metal sheet. Moreover, the first metal element **16** is coupled to the first connection point **123** of the ground element **12** via a first connection wire **15**, and a length of the first metal element **16** is at least 0.3 times a length of the ground element **12**.

Thus, the first metal element **16** can be used to adjust an equivalent resonant length of the ground element **12**. For instance, the equivalent resonant length of the ground element **12** can be increased by the first metal element **16**, so as to properly excite a resonant mode of the antenna element **13** or improve an impedance matching and a radiation efficiency of the antenna element **13** operated in a frequency band. Furthermore, because the first metal element **16** can be covered by the external connection element **14** formed by the non-conductive material, the first metal element **16** is not in direct contact with the user in actual application. Thus, the adjustment of the equivalent resonant length of the ground element **12**, made by the first metal element **16**, is not affected by the user.

FIG. **1**B is a diagram showing a return loss of the antenna element according to the first embodiment of the invention. In this embodiment, a size of the ground element **12** is about 45×40 mm^2. A length and a height of the antenna element **13** are about 30 mm and 10 mm respectively, and the antenna element **13** is formed on an FR4 substrate. Moreover, in this embodiment, an operation bandwidth of the antenna element **13** is defined by a return loss of 6 dB, that is, a voltage standing wave ratio (VSWR) of 3:1. As shown in FIG. **1**B, with the arrangement of the first metal element **16**, the frequency band in which the antenna element **13** is operated covers the frequency band of GSM1800.

FIG. **2** is a schematic view showing the structure of a communication device according to the second embodiment of the invention. Basically, a communication device **2** of the second embodiment is similar to the communication device **1** of the first embodiment. The main difference between the second embodiment and the first embodiment is that the communication device **2** further includes an inductive element **21** and a second metal element **24**, and the ground element **12** further includes a second connection point **22** disposed near or at the second edge **122**.

More specifically, a first metal element **26** is coupled to the first connection point **123** via a first connection wire **25** and the inductive element **21**. The second metal element **24** is disposed outside the device casing **11** and supported by the external connection element **14**. For example, the second metal element **24** can be embedded in the external connection element **14**. Moreover, the second metal element **24** is coupled to the second connection point **22** of the ground element **12** via a second connection wire **23**, and a length of the second metal element **24** is at least 0.2 times the length of the ground element **12**.

Thus, the equivalent resonant length of the ground element **12** in different frequency bands can be adjusted respectively by the first metal element **26** and the second metal element **24** to improve the impedance matching and radiation efficiency of the antenna element **13** in different frequency bands, so that the antenna element **13** has the characteristic of multi-band operation. For example, the first metal element **26** can be used to adjust the equivalent resonant, length of the ground element **12** in a low frequency band, and the second metal element **24** can be used to adjust the equivalent resonant length of the ground element **12** in a high frequency band. Accordingly, the antenna element **13** can have better impedance matching in both the low frequency and high frequency resonant modes.

Further to the above, because the first metal element **26** is coupled to the first connection point **123** via the inductive element **21**, the first metal element **26** can improve the impedance matching of the antenna element **13** in the low frequency resonant mode without affecting the impedance matching of the antenna element **13** in the high frequency resonant mode. Besides, the first metal element **26** and the second metal element **24** can be covered by the external connection element **14** formed by the non-conductive material. Therefore, the first metal element **26** and the second metal element **24** are not in direct contact with the user in actual application. Thus, the adjustments of the equivalent resonant length of the ground element **12**, made by the first metal element **26** and the second metal element **24**, are not affected by the user. Other parts of the structure of the communication device **2** are identical or similar to those of the first embodiment and thus will not be repeated hereinafter.

FIG. **3** is a diagram showing a return loss of the antenna element according to the second embodiment of the invention. In this embodiment, a length of the first metal element **26** is about 35 mm. An inductance value of the inductive element **21** is about 20 nH. A length of the second metal element **24** is about 18 mm. A length of the loop structure, formed by the external connection element **14** and the device casing **11**, is about 230 mm. In addition, a return loss curve **31** indicates a return loss when the first metal element **26** and the second metal element **24** are not added. A return loss curve **32** indicates a return loss when the first metal element **26** and the second metal element **24** are added.

As shown by the return loss curve **31**, in the situation that the first metal element **26** and the second metal element **24** are not added, the antenna element **13** only covers the frequency band of GSM1800 (about 1710-1880 MHz). That is to say, the antenna element **13** only has the characteristic of operating in one single frequency band. On the other hand, as shown by the return loss curve **32**, in the situation that the first metal element **26** and the second metal element **24** are added, the antenna element **13** can not only be operated in a low frequency band to cover the frequency band of GSM900 (about 880-960 MHz) but also operated in a high frequency band to cover the frequency band of GSM1800/1900 (about 1710-1990 MHz). In other words, with addition of the first metal element **26** and the second metal element **24**, the antenna element **13** has the characteristic of operating in multiple frequencies.

FIG. **4** is a diagram showing an antenna efficiency of the antenna element according to the second embodiment of the invention. Specifically, an antenna efficiency curve **42** indicates an antenna efficiency (the radiation efficiency including the return loss) when the first metal element **26** and the second metal element **24** are not added. An antenna efficiency curve **41** indicates an antenna efficiency (the radiation efficiency including the return loss) when the first metal element **26** and the second metal element **24** are added. It is clearly known from FIG. **4** that, with addition of the first metal element **26** and the second metal element **24**, the antenna efficiency of the antenna element **13** can be improved from the antenna efficiency curve **42** to the antenna efficiency curve **41**. As a result, the antenna efficiency of the antenna element **13** reaches 51% to 71% in the frequency band of GSM900 and reaches 59% to 87% in the frequency band of GSM1800/1900, and thus the communication device is suitable for multi-band operation of mobile communication.

FIG. **5** is a schematic view showing the structure of a communication device according to the third embodiment of the invention. Basically, a communication device **5** of the third embodiment is similar to the communication device **1** of the first embodiment. The main difference between the third embodiment and the first embodiment is that the first metal element **56** includes a first portion **561** and a second portion **562**, and an inductive element **51** is inserted between the first portion **561** and the second portion **562**. More specifically, the first portion **561** is coupled to the first connection point **123**,

and the first portion **561** is coupled to the second portion **562** via the inductive element **51**. In other words, it can be regarded that the inductive element **51** separates the first metal element **56** into the first portion **561** and the second portion **562**. Moreover, a length of the first portion **561** is at least 0.2 times a length of the second portion **562**.

It should be noted that the first portion **561** can be used to adjust the impedance matching and radiation efficiency of the antenna element **13** in a high frequency band. In addition, because the inductive element **51** is inserted between the first portion **561** and the second portion **562**, the first metal element **56** can also be used to adjust the impedance matching and radiation efficiency of the antenna element **13** in a low frequency band. That is, the first metal element **56** can improve the impedance matching and radiation efficiency of the antenna element **13** in two different frequency bands to achieve effects similar to the second embodiment. Other parts of the structure of the communication device **5** are identical or similar to those of the first embodiment and thus will not be repeated hereinafter.

FIG. **6** is a schematic view showing the structure of a communication device according to the fourth embodiment of the invention. Basically, a communication device **6** of the fourth embodiment is similar to the communication device **2** of the second embodiment. The main difference between the fourth embodiment and the second embodiment is that a second metal element **64** is coupled to the second connection point **22** via a second connection wire **63** and an inductive element **61**, and the communication device **6** further includes at least one connection wire **65**.

More specifically, the second metal element **64** and the first metal element **26** are electrically connected by the at least one connection wire **65**. Accordingly, the second metal element **64** and the first metal element **26** are equivalent to a larger metal sheet for further improving the impedance matching of the antenna element **13** in a resonant mode. Moreover, the second metal element **64** is coupled to the second connection point **22** via the inductive element **61**. Thus, the flexibility of using the second metal element **64** to adjust the equivalent resonant length of the ground element **12** is increased. Due to the similar structures, the communication device **6** of the fourth embodiment achieves effects similar to the second embodiment. Other parts of the structure of the communication device **6** are identical or similar to those of the second embodiment and thus will not be repeated hereinafter.

It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed embodiments without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the invention covers modifications and variations of this disclosure provided that they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A communication device, comprising:

a device casing, wherein a ground element and an antenna element are disposed in the device casing, the ground element comprises a first edge, a second edge opposite to the first edge, and a first connection point, the first connection point is disposed near or at the second edge, and the antenna element is disposed near the first edge;

an external connection element formed by a non-conductive material and disposed outside the device casing, wherein the external connection element has a belt-like structure and is combined with the device casing to substantially form a loop structure;

a first metal element supported by the external connection element, wherein a first end of the first metal element is coupled to the first connection point;

a second metal element supported by the external connection element, wherein a first end of the second metal element is coupled to a second connection point of the ground element, second ends of the first metal element and the second metal element are open ends, and the second connection point is disposed near or at the second edge; and

at least one connection wire supported by the external connection element and disposed between the first metal element and the second metal element, wherein the second metal element is electrically connected to the first metal element via the at least one connection wire.

2. The communication device according to claim **1**, wherein the first metal element is coupled to the first connection point via an inductive element.

3. The communication device according to claim **1**, wherein the first metal element is embedded in the external connection element and includes at least a metal wire or a metal sheet.

4. The communication device according to claim **1**, wherein a length of the first metal element is 0.3 to 0.8 times a length of the ground element.

5. The communication device according to claim **1**, wherein the first metal element comprises a first portion and a second portion, the first portion is coupled to the first connection point and coupled to the second portion via an inductive element, and a length of the first portion is at least 0.2 times a length of the second portion.

6. The communication device according to claim **1**, wherein the second metal element is coupled to the second connection point via an inductive element.

7. The communication device according to claim **1**, wherein the second metal element is embedded in the external connection element.

8. The communication device according to claim **1**, wherein a length of the second metal element is 0.2 to 0.4 times a length of the ground element.

* * * * *